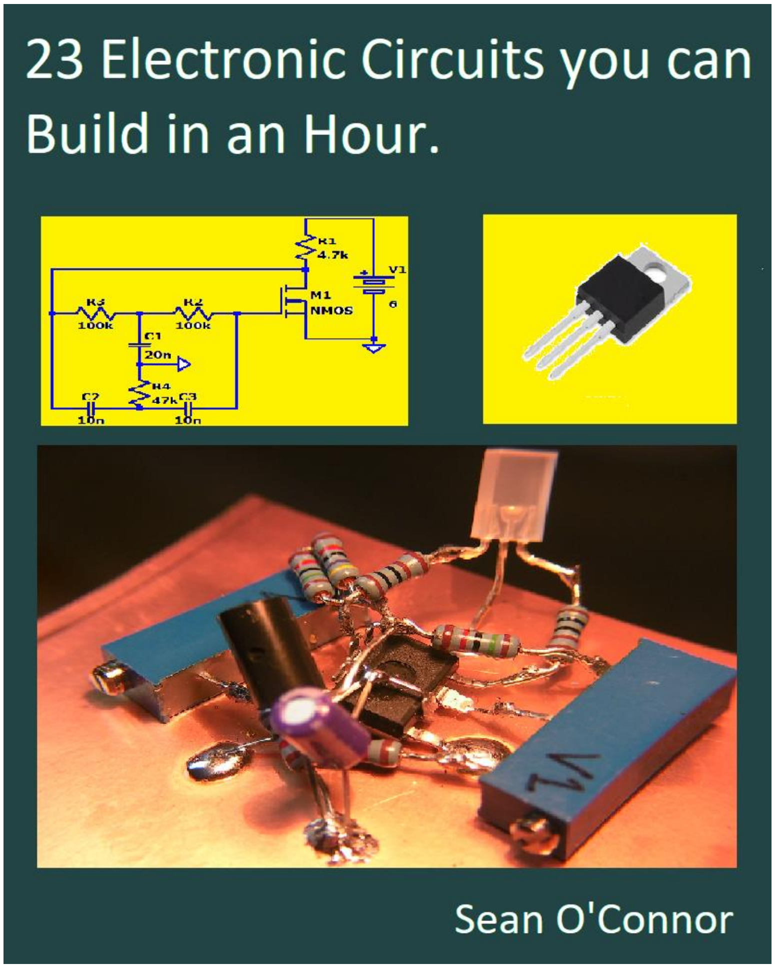

23 Electronic Circuits you can Build in an Hour.

Sean O'Connor

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Introduction.

While many people remain interested in designing and building analog electronic circuits, we all live busy lives these days. In this project book a carefully selected collection of easy to build circuits is presented. All the circuits can be built in under an hour using ugly bug construction, on a matrix board or even using a prototyping breadboard. All the circuits are chosen to be interesting in one way or another and can be adapted for a multitude of uses. All the circuits presented can be constructed with any of the most common NPN or PNP transistor types such as the 2N2222, BC549, 2N4401 (NPN) or A1015, BC857, BC557 (PNP). You should avoid extremely high power or extremely high frequency semiconductor types that have low Hfe or other issues.

Circuit 1. LEDs as Photodiodes.

You can use a LED as a photodiode, however the current generated by shining light on the device is tiny. Often too small to be measured with multimeter. That is because the receptive area of the semiconductor junction is not manufactured with such an application in mind.

In figure 1 the current generated by the LED D1 is multiplied by the Hfe (current gain) of Q1 and then multiplied again by the Hfe of Q2. The gain is typically in the order of 90000 (300*300). Even so a reasonable amount of light is needed to activate the indicator LED D2.

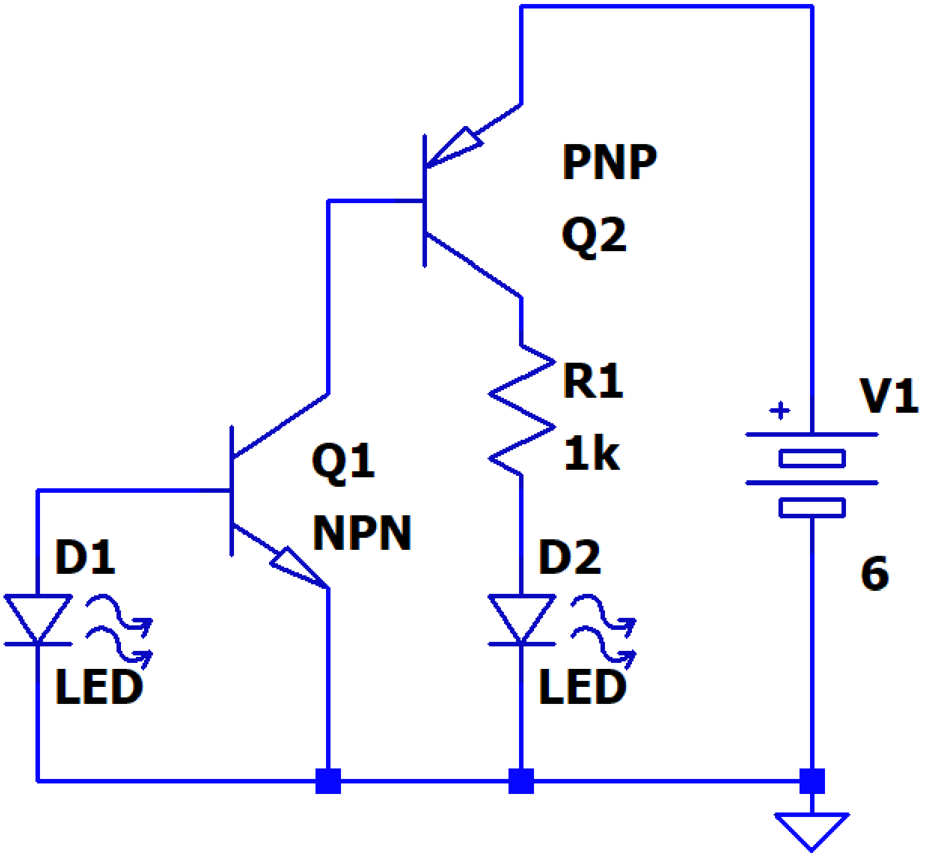

Figure 1. Using a LED as a photodiode.

The circuit is very sensitive to external noise, such as mains hum, it is a good idea to keep the circuit leads short. The circuit also relies on the low leakage characteristics of modern transistors. If the circuit were operated at especially high temperatures leakage might become an issue.

For practical applications you could replace the load R1 and D1 with something more useful. Like a reed relay with a reverse biased diode to protect Q2 from inductive voltage spikes. You can experiment with other semiconductor junctions open to light, such a glass enclosed signal diodes.

Circuit 2. Zener diode as a noise generator.

It is well known that Zener diodes are very noisy when used in their normal (reverse bias) breakdown mode. In practical circuits the issue is largely resolved by using filtering capacitors to remove the noise. However, noise signals are useful for testing both audio and radio frequency (RF) equipment. The circuit in figure 2 is optimally set up to extract RF noise. Q1 is used in common base mode meaning the Zener diode ZD1 sees a very low impedance at the transistor's emitter. This low impedance prevents semiconductor junction capacitances from filtering away the higher frequency components of the noise. The current based noise signal is converted to a voltage signal at the collector of Q1 by R1.

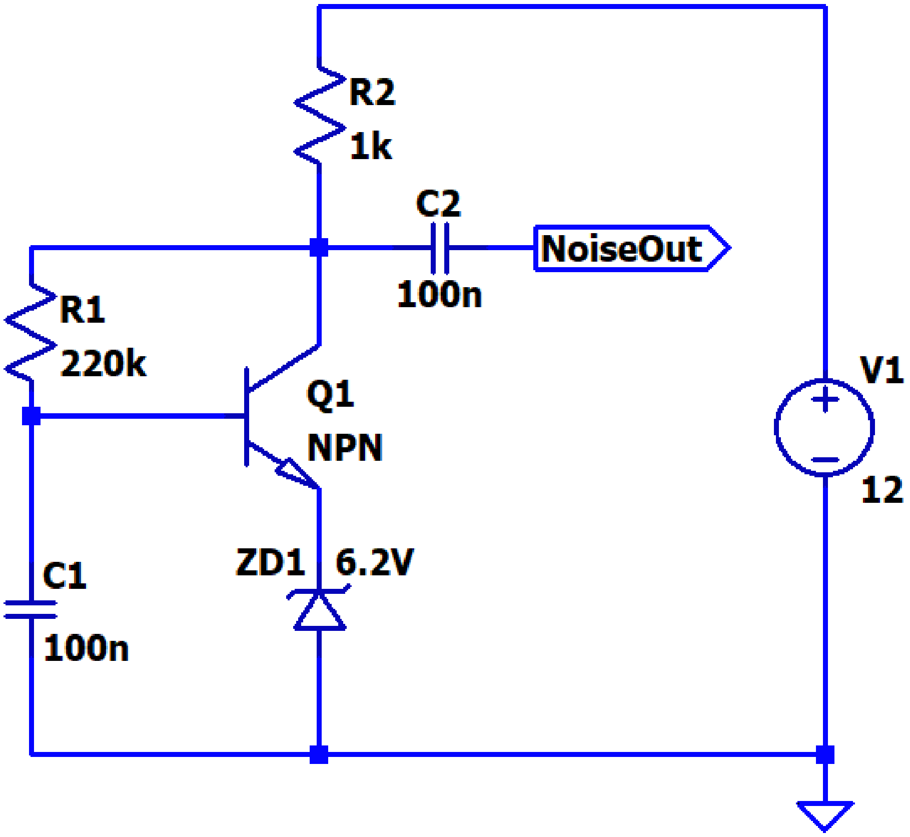

Figure 2. A Zener diode used as a noise generator.

The base emitter junction of a standard transistor has a low reverse bias breakdown voltage like a Zener diode and is even noisier. You can use it as an alternative to a Zener diode in the circuit.

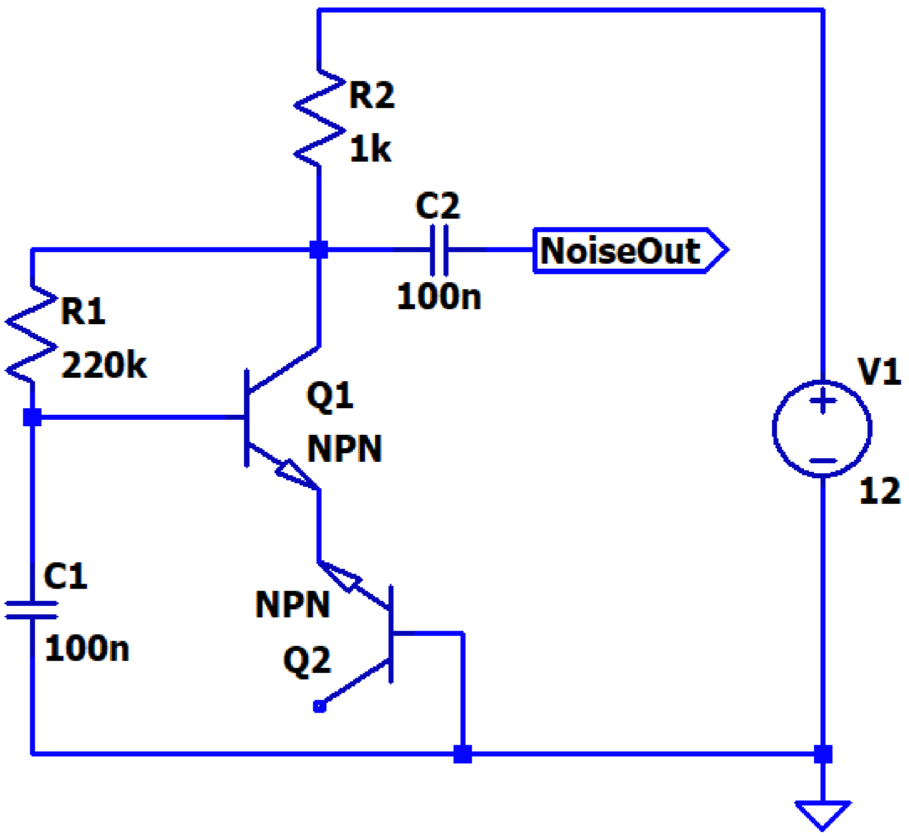

Figure 3. A reverse biased transistor base emitter junction used a noise generator.

If you use a radio receiver to detect the noise, the narrow bandwidth of the receiver will filter out most of the power of the random signal, because the noise power is actually spread over a very wide range of frequencies. It is also possible to use an RFC (inductor) in place of R2 to get a greater output. In which case R1 should be increased to about 1 Meg.

Circuit 3. An AM (radio) detector circuit.

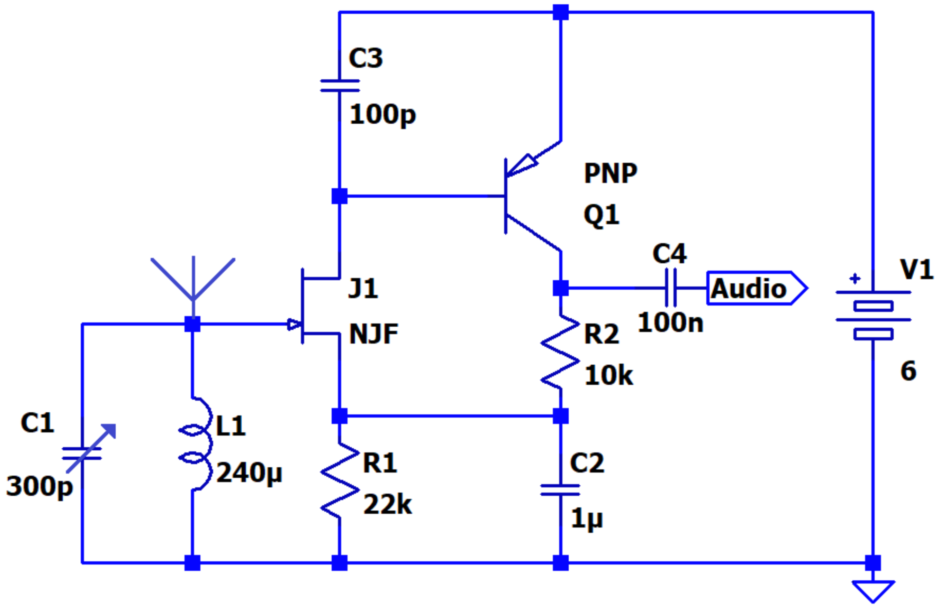

Figure 4. An AM radio detector circuit.

The DC behavior of FET J1 is that of a source follower with help from Q1. Q1 pulls up the voltage at the source of J1 through R2 until the FET J1 is just pinched off. You can pinch off a FET by making the gate voltage very negative, or equivalently increasing the source voltage relative to the gate as in the example here. Only a small amount of current then flows through J1, just enough that when amplified by Q1 it creates nearly the pinch off voltage at the source of the FET.

An AC voltage signal at the gate of J1 is amplified in an uneven way. Positive going parts of the signal will be amplified more than negative going parts of the signal due to the non-linear behavior of FETs. Only a very small capacitance is needed to remove the RF component of the signal at the drain of the FET due to the tiny currents involved. This is done by C3. Q1 then amplifies the separated audio component with the aid of R2. The capacitor C2 is needed both as a RF bypass and an audio bypass. You can use a 1uf ceramic capacitor or an electrolytic capacitor in parallel with a 100nf ceramic capacitor. Since the gate of the FET is very negative biased there will be almost no loading on the tuned circuit and very little varactor effect from the gate source semiconductor junction. Selectivity then is primarily determined the Q of the LC resonant circuit involved. If the resonant circuit was a magnetic loop antenna the Q could be very high (e.g., 3000), however in most cases it will be around 100.

Circuit 4. A square wave oscillator.

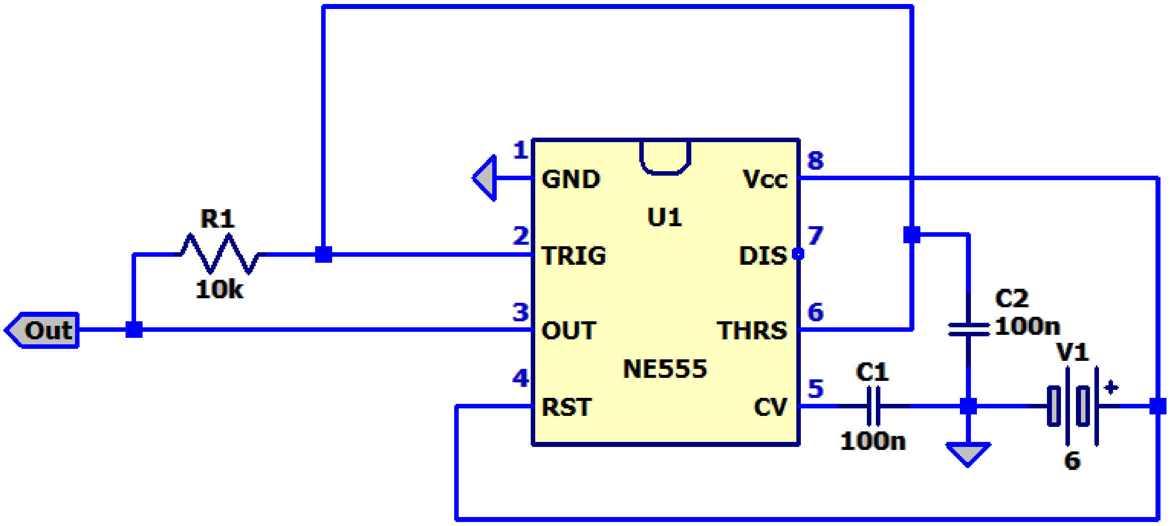

Figure 5. A 50-50 duty cycle square wave oscillator using the NE555.

This is the lowest component oscillator you can make using the NE555. You should be able to omit C1 in most cases for an even further reduction. The output is a square wave with an approximate duty cycle of 50-50 except for the first pulse. The frequency is f=1/(1.4*R1*C2) which is 714Hz with the component values given. Since the output has sharp on off edges you could loosely couple it to a LC resonant circuit via a current limiting resistor to set a LC circuit ringing, similar to early spark gap transmitters. Another application is to generate voltage rail to power op-amp circuits.

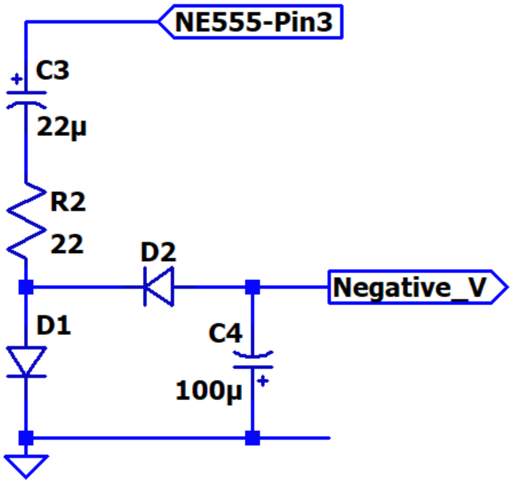

Figure 6. A negative voltage generator.

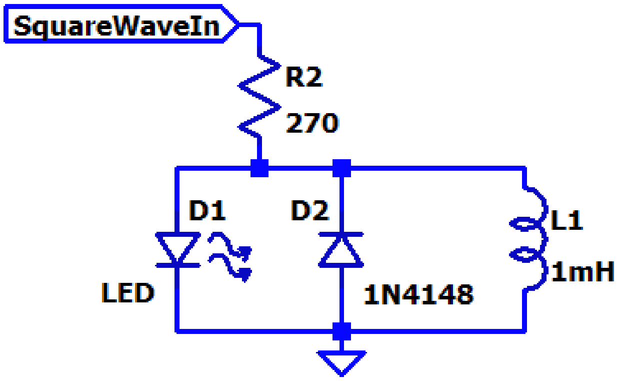

Figure 7. LED nanosecond light pulse device.

You can also create nano second light pulse generator, as shown in figure 7. When the square wave becomes positive the LED D1 lights momentarily until the current drawn by L1 increases to the point where it effectively shorts the LED out. D2 protects the square wave generator from voltage pulses generated by L1 when current through it stops flowing. The full circuit is then:

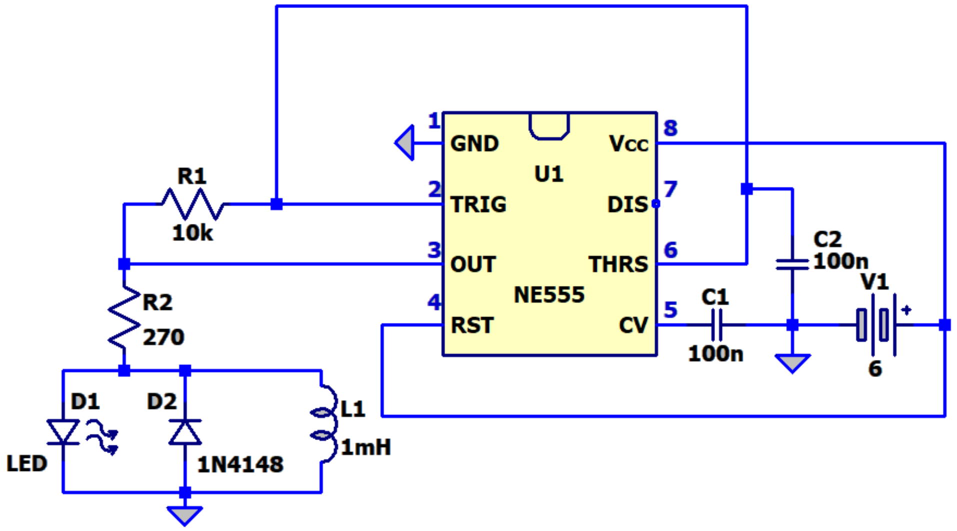

Figure 8. LED nanosecond light pulser with drive circuit.

Circuit 5. A TL431 headphone amplifier.

The TL431 is shunt voltage regulator that internally contains a high gain differential amplifier. The TL431 is very common in phone charger circuits etc.

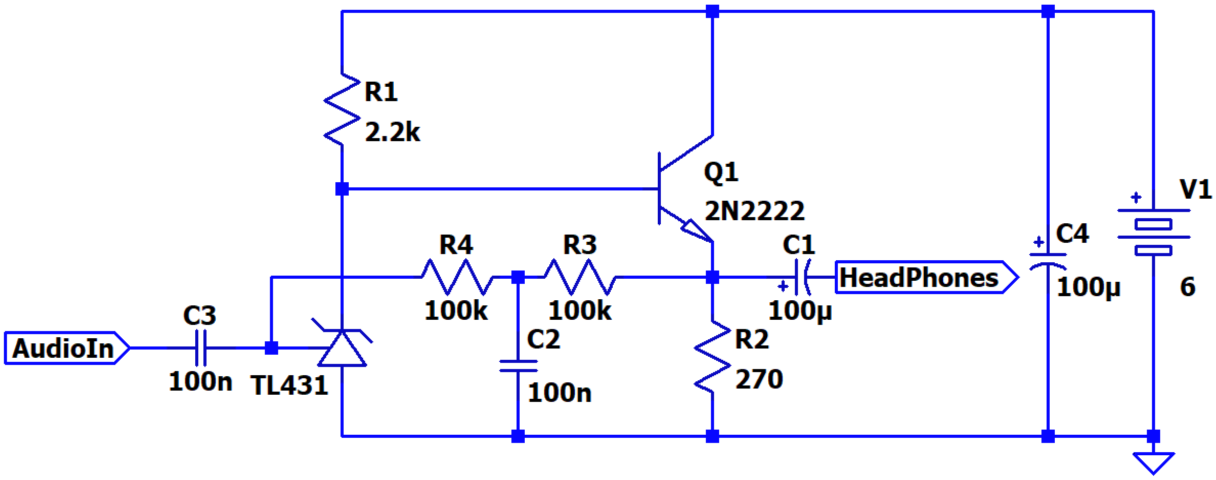

Figure 9. A TL431 headphone amplifier.

If you connect headphones directly to the TL431 you will lose a lot of gain due to the impedance mismatch involved. The emitter follower circuit using Q1 can drive 32-ohm headphones up to a reasonably loud volume and provides a suitable low impedance match up to a limited voltage swing range. The output impedance actually being lower than R2 over that limited range. Of course, decreasing R2 will increase the drive voltage range at the expense of a higher average current draw. To prevent unwanted (shunt) negative feedback C2 is included in the bias circuit between R3 and R4. The circuit has a voltage gain of about 1000, making it suitable for use with crystal sets etc.

Circuit 6. A quasi push-pull audio amplifier.

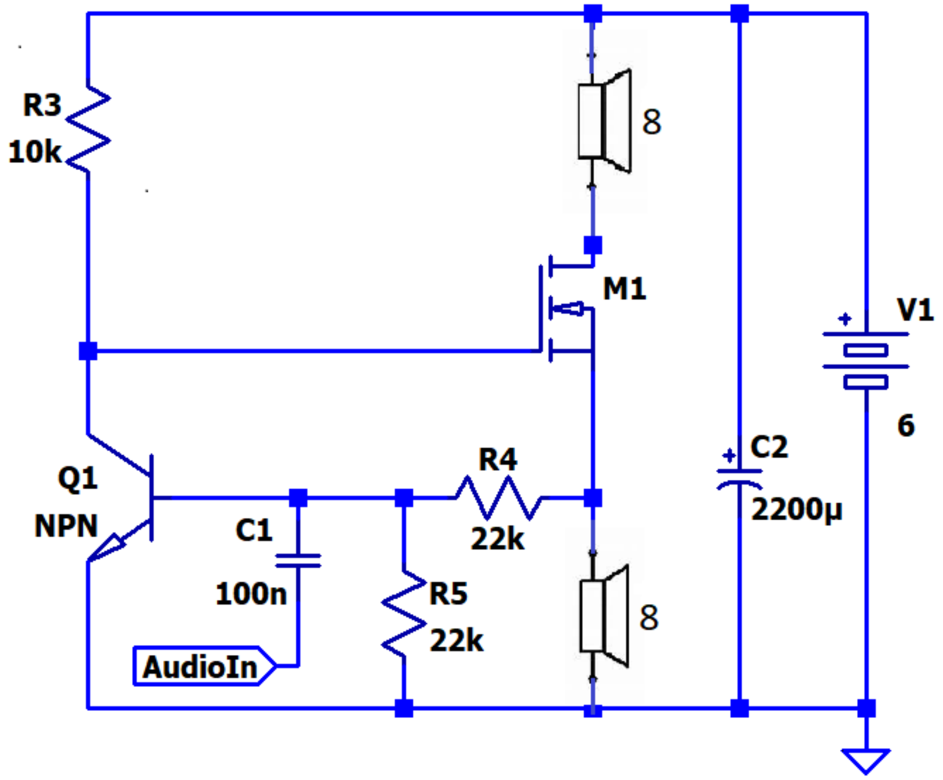

Figure 10. A quasi push-pull class A audio amplifier using 2 loudspeakers.

The MOSFET M1 is used as a source follower feeding directly the lower loudspeaker. The current in the upper loudspeaker follows exactly the current in the lower speaker. The transistor Q1 starts conducting when the voltage at its base is about 0.7 volts or when there is 1.4 volts across the lower loudspeaker (R4 and R5 causing division by 2.) The voltage at the drain also falls by 1.4 volts.

Q1 also amplifies the audio input signal meaning a preamplifier is not needed in many applications. The input impedance of the amplifier is somewhat low being a few thousand ohms, which is a point to be aware of.

Circuit 7. A phase shift oscillator.

A phase shift oscillator is where each resistor capacitor pair cause a phase shift of approximately 60 degrees (180 degrees total) and the transistor amplifier provides the remaining 180 degrees to make the circuit work.

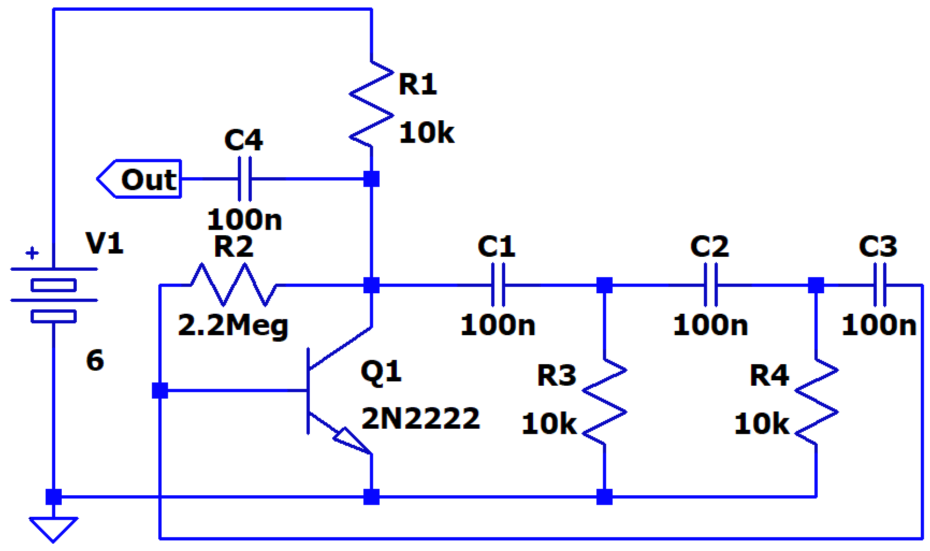

Figure 11. A phase shift oscillator operating at approximately 38 Hz.

Phase shift oscillators would make nice general purpose audio oscillators except the component values that will allow it oscillate are quite picky. In this circuit R3 and R4 have to be quite low for the circuit to function. Where you might incorrectly expect higher values to work well. The best place to sample the output is at the collector of Q1 where a very strong and reasonably sinusoidal output appears.

Circuit 8. Thermistor temperature indicator.

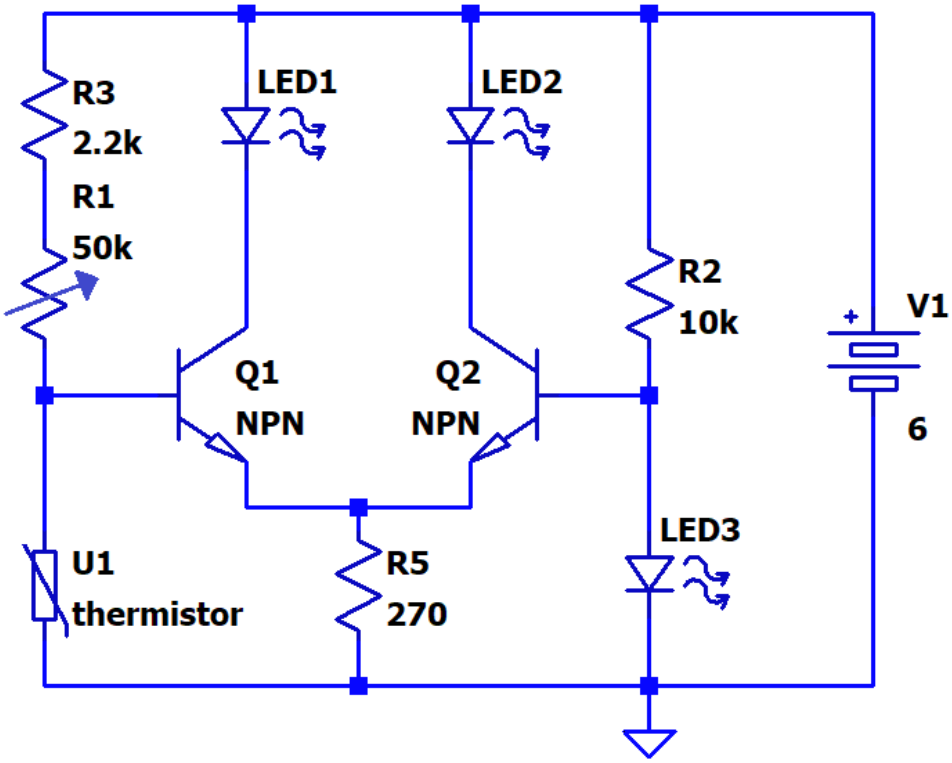

Figure 12. A thermistor temperature indicator using a transistor differential pair.

LED3 is used as a voltage reference for the differential pair Q1 and Q2. As the voltage at the base of Q1 varies over about 26 mV Q1 will stop conducting and Q2 start conducting, depending on whether it is less than the reference voltage at the base of Q2 or greater than the reference voltage. Since the LED1 and LED2 get warm when lit you can place the thermistor next to the LED that lights when warm to get some positive feedback. Driving the circuit decisively one way or the other.

Circuit 9. A bucket voltage regulator.

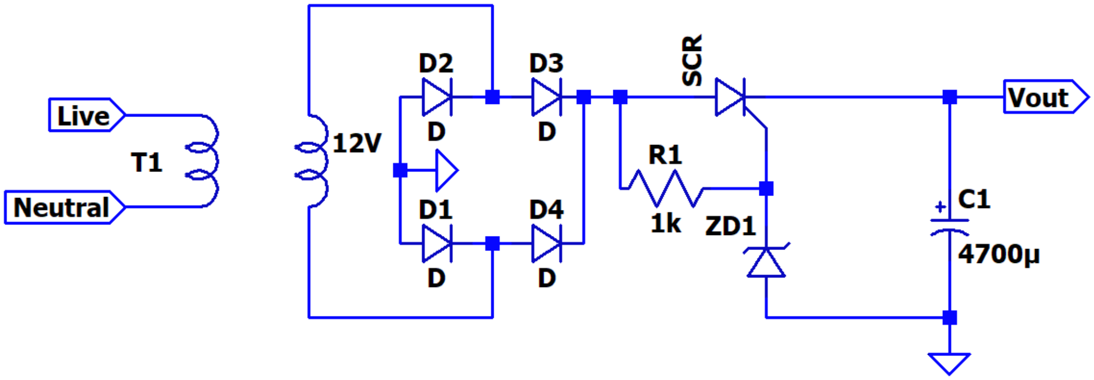

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Figure 13. A high current bucket regulator that can regulate voltage to within 5 to 10%.

It is assumed that Transform T1 is fully enclosed to avoid safety concerns. For example, some wall adapters provide AC out. The above circuit can regulate voltage to within 5 to 10 percent for high current applications. The required voltage is set by the Zener diode ZD1. When the output voltage is less than that of ZD1, positive current pulses from the output of the bridge rectifier D1 to D4 go through the resistor R1 and through the gate of the SCR, causing it to conduct. In that way charging C1 with the rectified voltage pulse. When the output voltage is high enough the current is diverted away from the SCR gate by the Zener diode ZD1 and the SCR remains off.

You can use an LED or a number of LEDs in series in place of the Zener diode. The light output of the LED(s) can serve as an inverse load indicator.

Circuit 10. A scintillation detector.

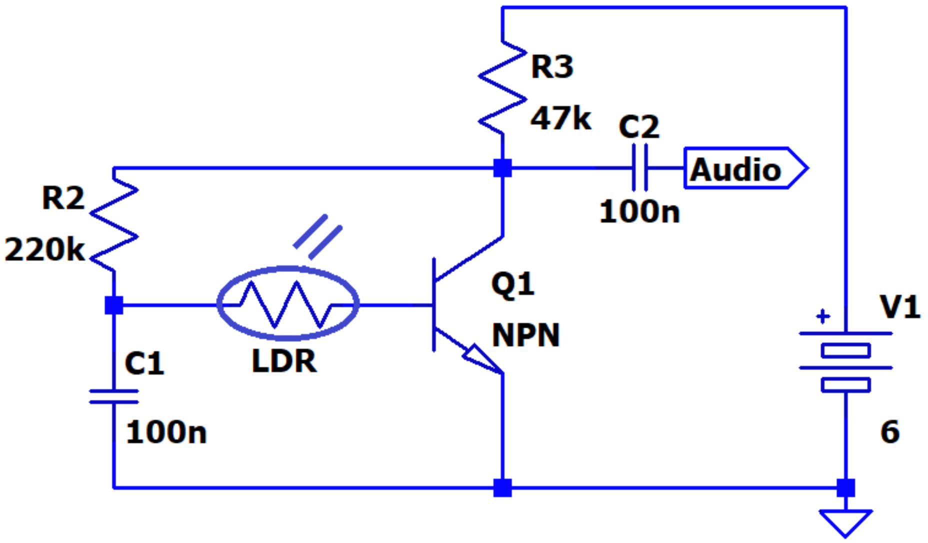

Figure 14. A scintillation detector using a light dependent resistor LDR.

The resistive element of light dependent resistor is actually made of a semiconductor which is sensitive to more than visible light. If beta or gamma particles hit the LDR the resistance of the LDR falls for a few milliseconds. The change in current caused is amplified by Q1 and fed to an audio amplifier. The LDR must be fully shielded from light. For example, it could be dipped in molten black crayon wax, leaving the 2 leads exposed.

Circuit 11. A boosted audio preamplifier.

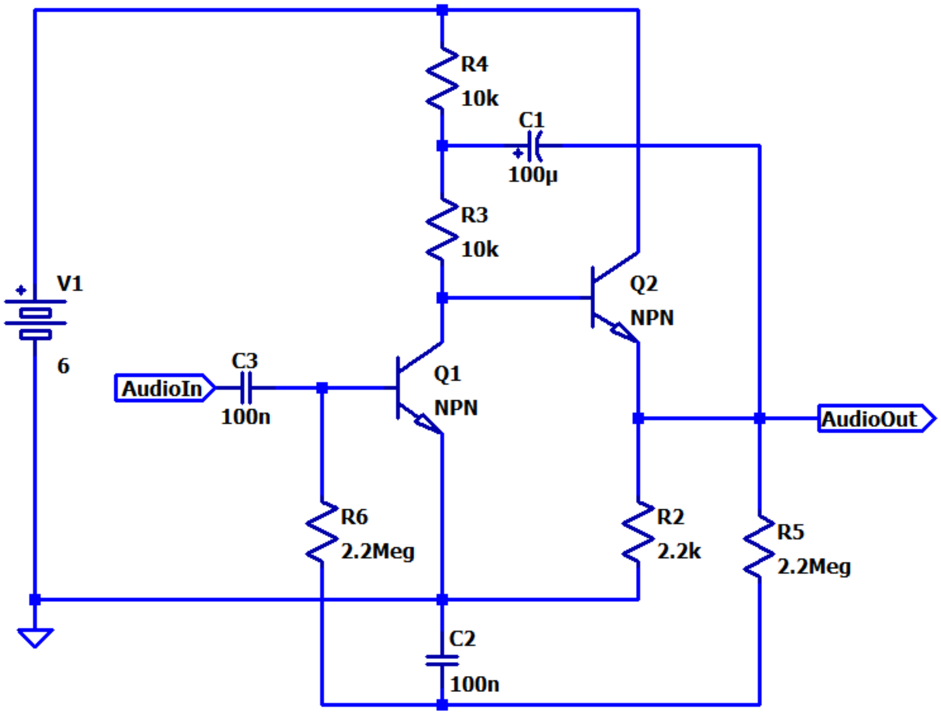

Figure 15. An audio preamplifier with boosted load impedance.

Q1 is used as a common emitter amplifier, followed by Q2 acting as an emitter follower. Biasing is provided through R5 and R6 with C2 preventing unwanted negative feedback. Changes in the collector voltage of Q1 are copied at the emitter of Q2 and fed back through C1 to the upper side of R3. This effectively multiples the resistance of R3 many times. Giving a high gain (1000+) audio preamplifier with low output impedance. The low output impedance of the preamplifier is useful for reducing mains hum from lead pickup in situations where the power amplifier is far away. You can reduce any distortion caused by the preamplifier to very low levels by including a low valued resistor into the emitter of Q1.

Circuit 12. An automatic volume control.

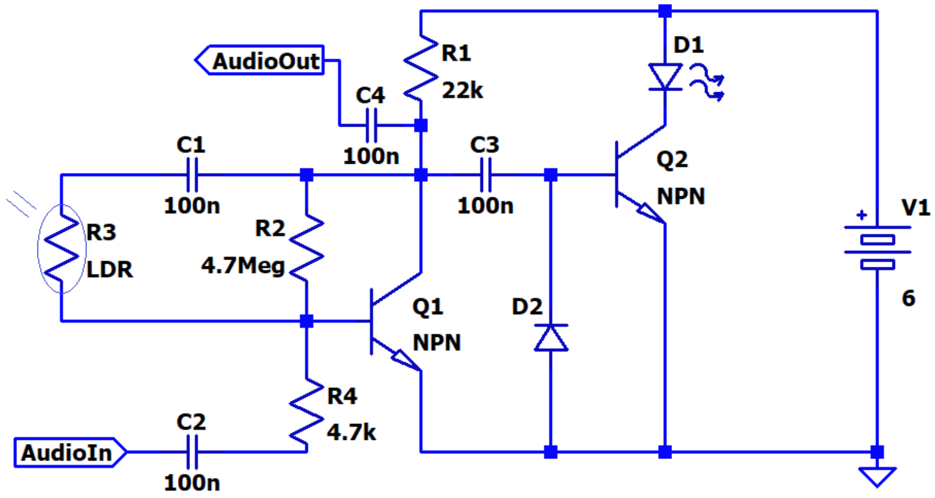

Figure 16. An automatic volume control using a light dependent resistor.

Q1 acts as a common emitter audio amplifier. Biasing is achieved through R2. The light dependent resistor LDR controls the amount of negative feedback involved. At low light levels very little negative feedback occurs. At high light levels the circuit provides minimal audio gain as the resistance of the LDR falls to about 10k when fully illumined.

When the audio level at the collector of Q1 exceeds 0.7 volts Q2 starts to conduct the LED D1 lights. If the LED and the LDR are correctly mounted together in a light-tight enclosure the circuit will act as an automatic volume control. The diode junctions of D2 and the base emitter junction of Q2 further act to clip any sudden impulse noise. Which is very useful if listening to a sensitive radio using headphones. Placing an electrolytic capacitor (10uf to 100uf) in parallel with the collector emitter of Q2 can help reduce any distortion from the LED flickering.

Circuit 13. A sensitive Schmitt trigger.

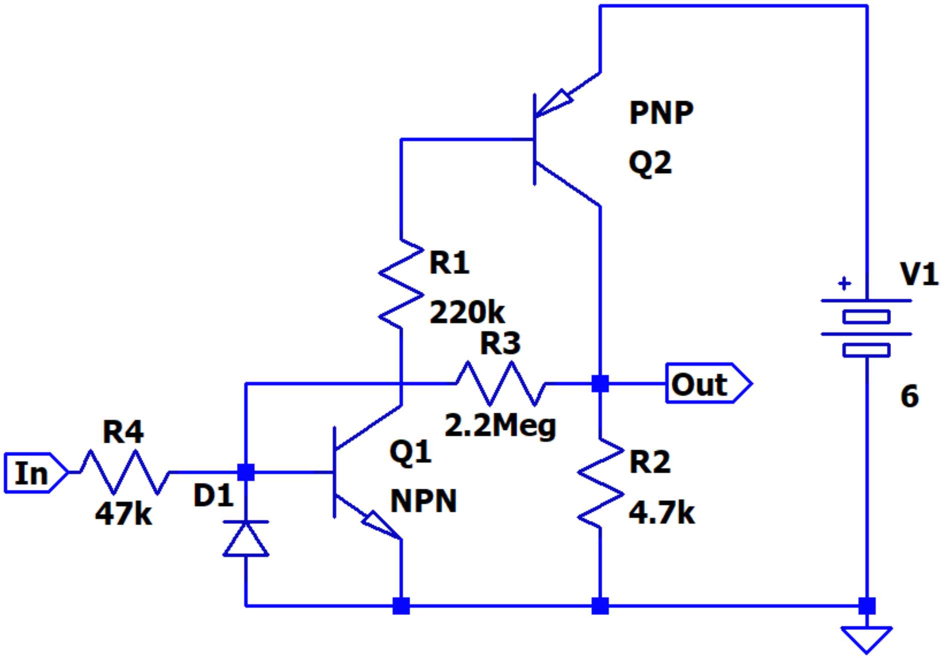

Figure 17. A sensitive Schmitt trigger circuit with a wide input voltage range.

When the input voltage exceeds a few hundred millivolts Q1 just starts to conduct and the current goes straight into the base of Q2 which then starts to strongly conduct. The voltage at collector of Q2 is pulled up causing current to flow through R3 into the base of Q1. Resulting in positive feedback. The circuit snaps on. To snap the circuit off the voltage at the input has to fall close to ground, such that the voltage at the input falls a few 10s of millivolts below that needed to trigger the circuit initally. D1 protects the base of Q1 from very negative voltages.

Circuit 14. Sound trigger circuit.

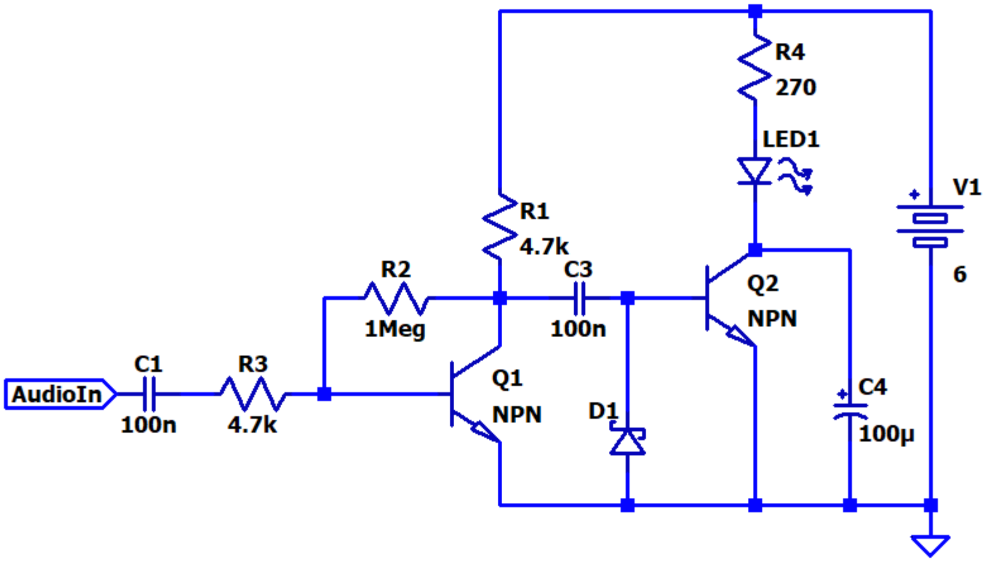

Figure 20. A sound trigger circuit.

Q1 amplifies an incoming audio signal. When the amplified signal exceeds a few hundred millivolts Q2 starts to conduct. D2 can be a regular signal diode or for greater sensitivity a Schottky diode for greater sensitivity. During a positive signal peak C3 charges through the base emitter junction of Q2. During a negative signal peak C3 discharges through D2, ready to be charged again. C4 smooths out the current pulses at the collector of Q2. You can replace the load R4 and LED D1 with any suitable alternative.

Circuit 15. Differential pair oscillator.

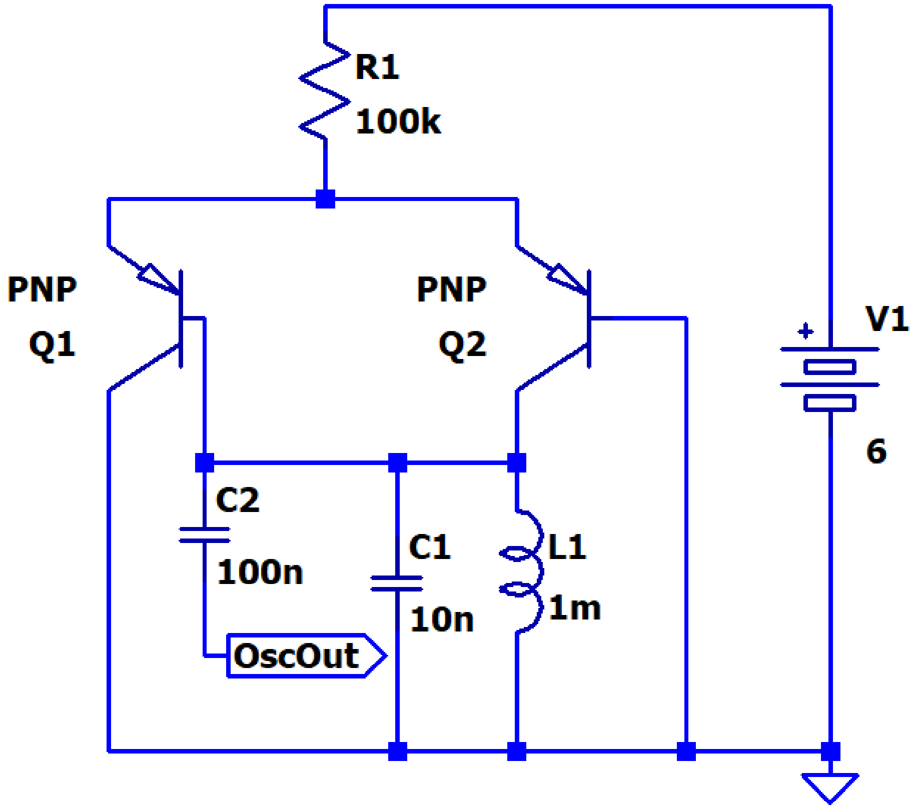

Figure 21. A differential pair audio or radio frequency oscillator.

Q1 and Q2 form a differential pair biased entirely through R1. L1 and C1 form the frequency determining resonant circuit. Positive feedback is obtained by connecting the resonant circuit to the base of Q1. The circuit is suitable for audio up to radio frequencies with a suitable choice of components. At higher frequencies R1 may need to be reduced to sustain oscillation.

Circuit 16. Current pulse circuits.

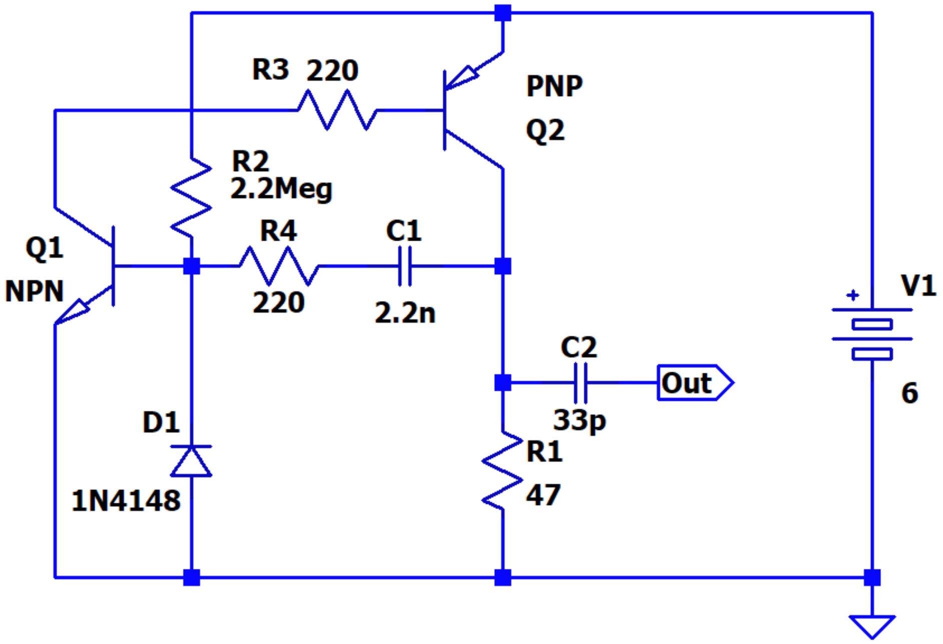

Figure 22. A signal injector for repairing audio and radio equipment.

At switch on, R2 allows Q1 to conduct. Q2 then conducts strongly, pulling upward the voltage at the collector of Q2. C1 then charges and provides positive feedback through the base of Q1. When C1 has fully charged current stops flowing through it. The voltage at the collector of Q2 falls and the base of Q1 is pulled negative. Eventually the cycle repeats again. Very short sharp pulses of current flow through Q2 that are ideal for fault finding in audio and radio receiver circuits. The pulses occur at audio frequency but have harmonics way up into the radio frequency spectrum. You should only have one wire from this circuit going to the equipment under test because the output is very strong and could cause damage if the full output power was unleashed.

The circuit in figure 22 contains a number of safety features. D1 prevents reverse bias breakdown of the base emitter junction of Q1. R3 and R4 act as current limiters. Often these components are omitted, as in figure 23.

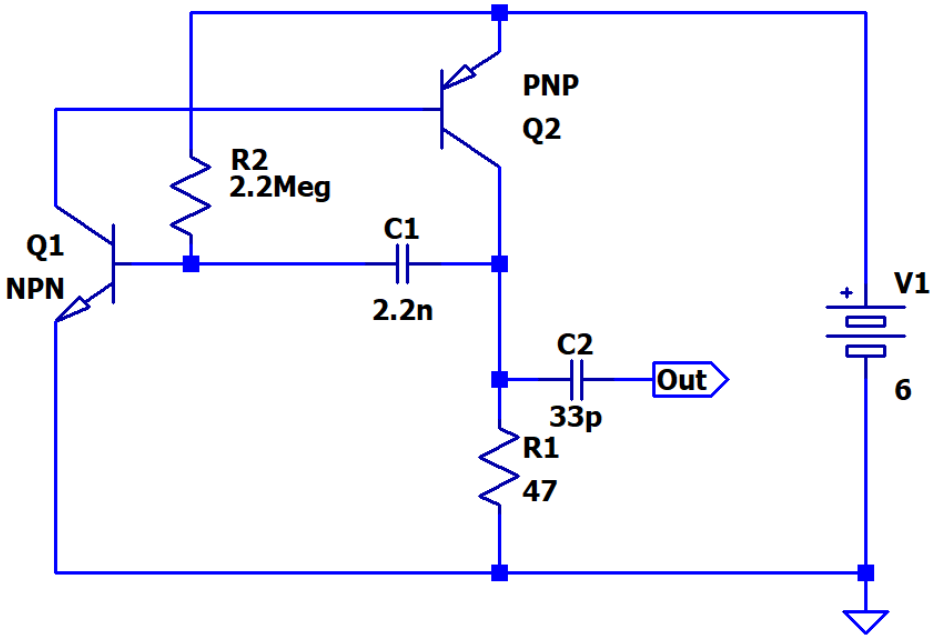

Figure 23. A less controlled signal injector.

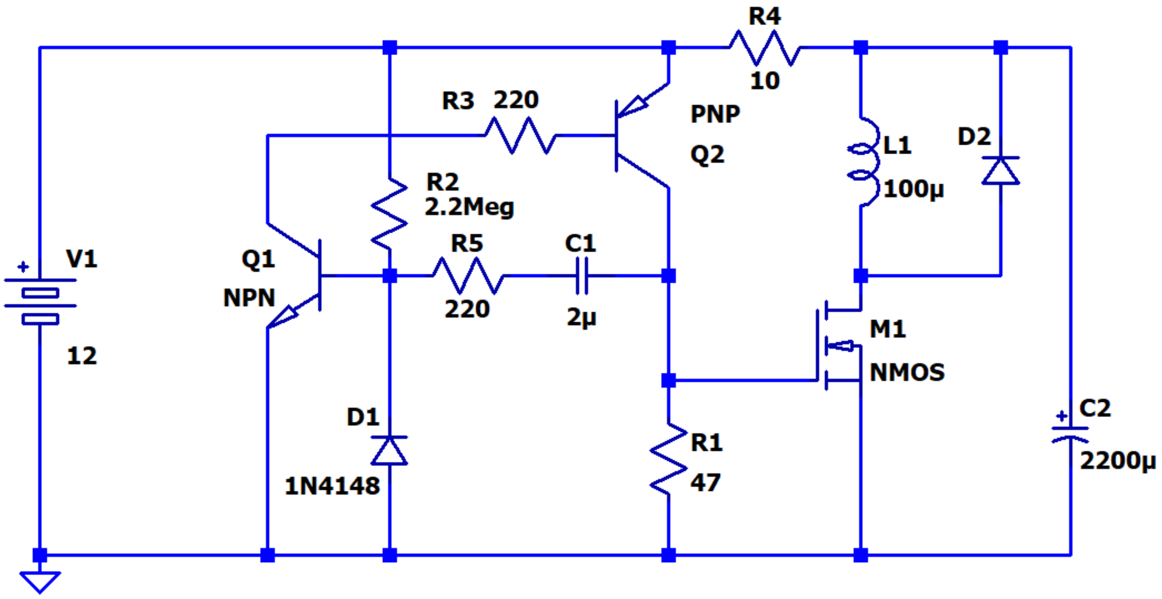

Figure 24. A high current pulse circuit.

The output of the current pulse generator is ideal for driving a MOSFET. In figure 24 when the MOSFET M1 conducts it allows a current of a few amps to build up in L1 producing a strong magnetic pulse. If you place a sheet of aluminum near L1 you can hear the magnetic impact. L1 can be a few turns of wire in a circular loop. One possibility is to make a metal detector producing very sharp current pulses and listening with a ground microphone(s) for a response.

Circuit 17. Negative resistance TRIAC pulser.

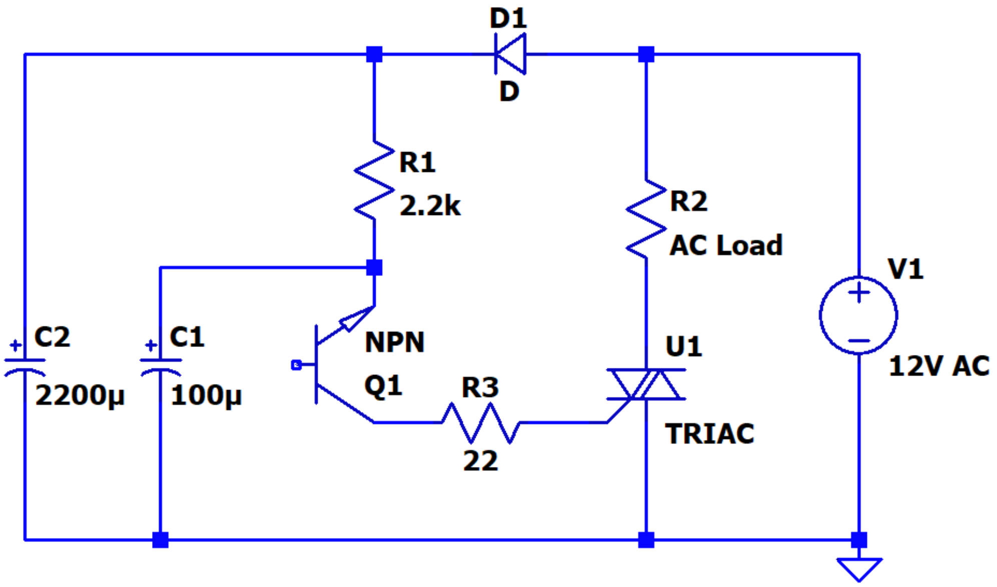

Figure 23. A negative resistance TRIAC pulser.

Some, but not all NPN transistors have emitter collector breakdown voltage characteristics suitable for generating pulse oscillation. As C1 slowly charges up, its voltage eventually reaches the emitter collector breakdown voltage of Q1 (10 to 12 volts.) At this point Q1 suddenly conducts, dumping the current charge in C1 into the gate of the TRIAC U1 via the current limiting resistor R3. This pulses the TRIAC into conduction momentarily. R2 can be any type of load that can accept positive or negative pulses. D1 needs to be a power diode such as an IN4007. You could substitute a loudspeaker or LED for the TRIAC gate. Then of course you can just power the circuit with a DC voltage.

Circuit 18. A TRF receiver.

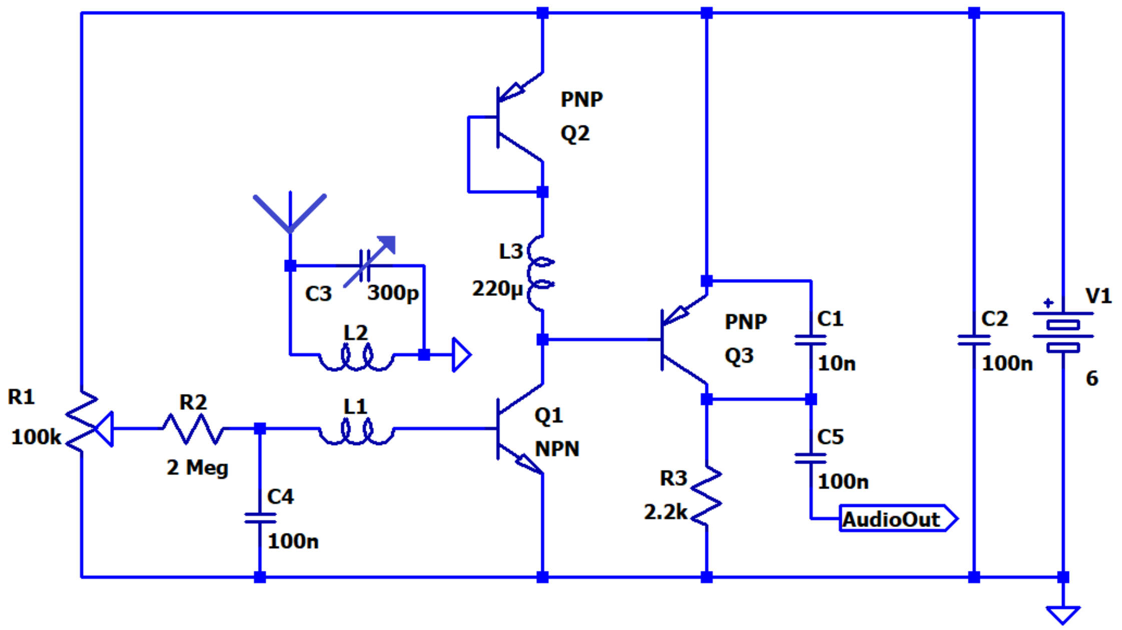

Figure 24. A turned radio frequency (TRF) receiver.

The tuned circuit L2 and variable capacitor C3 select out a radio signal from the antenna. L1 is on the same former as L2 meaning they are magnetically coupled using a turns ratio of about 1:7. If L2 has 14 turns then L1 should have about 2 turns. The radio frequency signal coupled into L1 is amplified by Q1. The gain provided by Q1 is controlled by the potentiometer R1. Since L3 (a radio frequency choke - RFC) is basically a short at DC, Q2 and Q3 form a current mirror. The current flowing through the collector of Q1 is mirrored at the collector of Q3. Since Q2 and Q3 are not matched the current mirror may be slightly off the normal 1 to 1 ratio.

Because the RFC L3 has high impedance at RF any RF signals at the collector of Q1 are diverted directly into the base of Q3. The non-linear behavior of both Q1 and Q3 result in efficient AM detection, making the circuit quite sensitive.

R3 can be replaced by a high value inductor (1H+) for greater output volume. For example, a ballast inductor from an old fluorescent lamp will work well. The lower the power rating the better.

If the RFC L3 is made by winding 20 or 30 turns on a ferrite core (such as from an old power supply or CFL bulb) you can turn the circuit into a regenerative receiver. You put an independent single turn of wire through the ferrite core in addition to the original turns and then connect that to 1 or 2 turns around L2. If you connect it the correct way around you get controlled positive feedback adjustable by R1. That results a major boost to selectivity and gain. Connect it the wrong way around and you get the opposite effect. You can adjust the amount of positive feedback to the point where the circuit just starts to oscillate. That allows you to then receive CW and SSB signals on the amateur radio bands.

Circuit 19. A wind speed indicator.

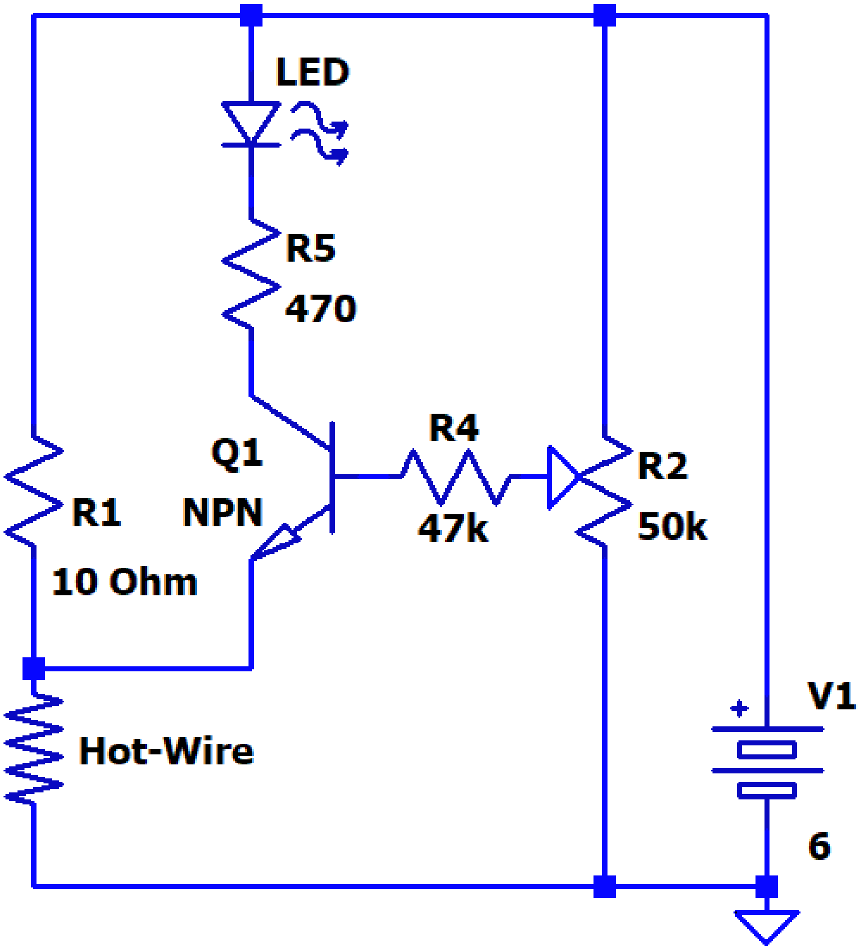

Figure 28. A wind speed indicator.

The filament from a broken open incandescent lightbulb is heated by the current flowing through the low value resistor R1. The resistance of the filament alters with windspeed due to the cooling effect. As the filament (hot wire) cools Q1 conducts more and lights the LED. The best value for R1 depends on the original voltage and power rating of the incandescent bulb involved. For small bulbs you could try 47 ohms for R1.

Circuit 20. An over current monitor.

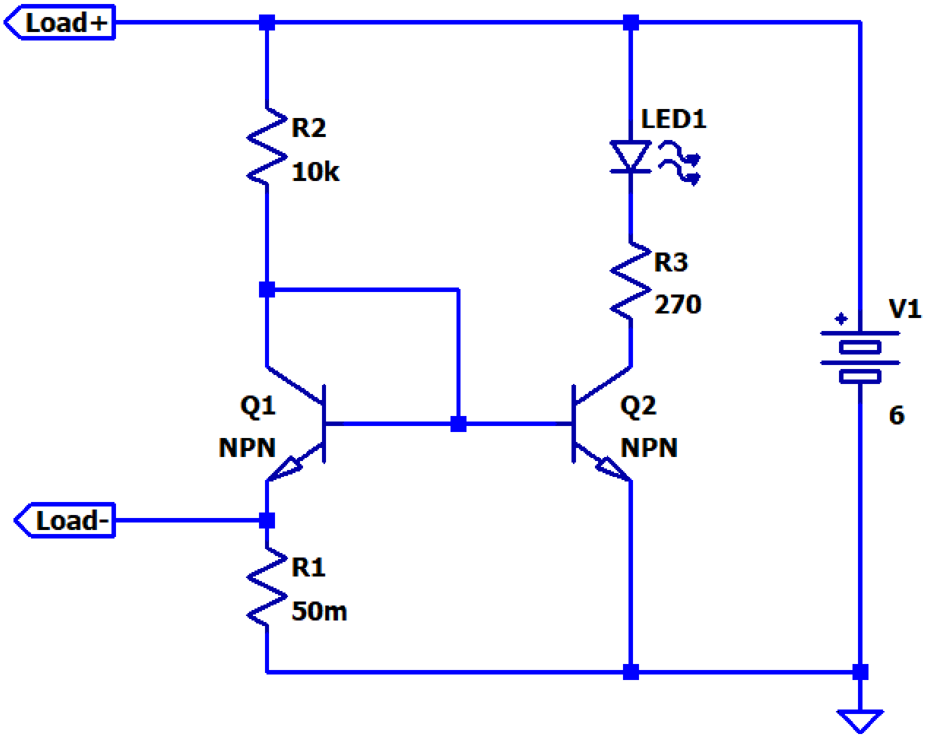

Figure 29. An over current monitor.

R1 is a very low value resistance in the milliohm range. It could be a PCB track or a short length of (thin) wire. In normal circumstances Q1 and Q2 act as an approximate current mirror. The small current flowing through R2 will be reflected at the collector of Q2. As the load current increases Q1 begins to turn off and all the current flowing through R1 ends up in the base of Q2. Lighting LED1 strongly.

Circuit 21. A current signal audio amplifier.

Sometimes you need to recover current based audio signal existing within an unknown bias current. Using a transformer is the easiest way to deal with this.

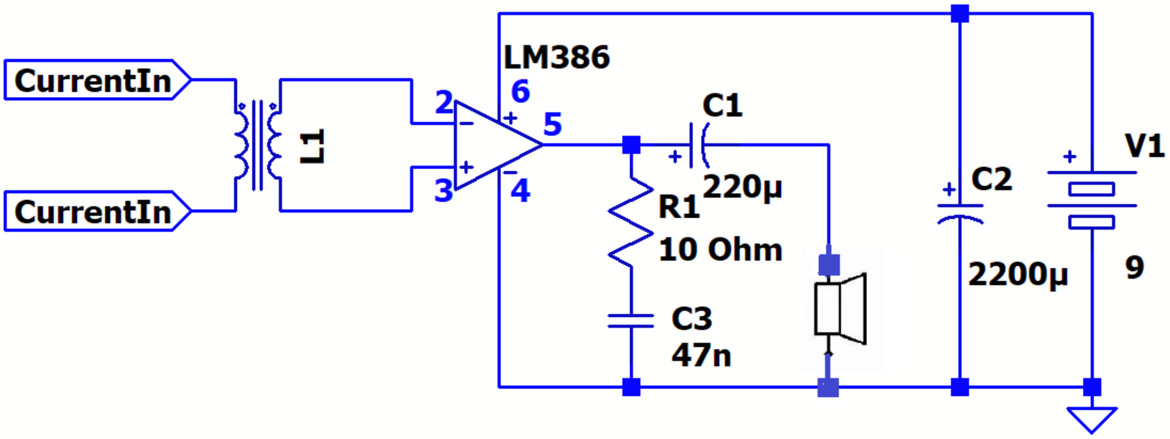

Figure 30. A current signal audio amplifier.

A small mains transformer can be used for this circuit or a 600 ohm audio transformer. In most cases the circuit works best with high impedance (high voltage) section connected to the LM386 IC. In many situations R1 and C3 are not needed, if you want to reduce the component count. An example use case is shown in figure 31 where you don't know the current flowing through the collector of Q1 due to transistor Hfe being rather variable.

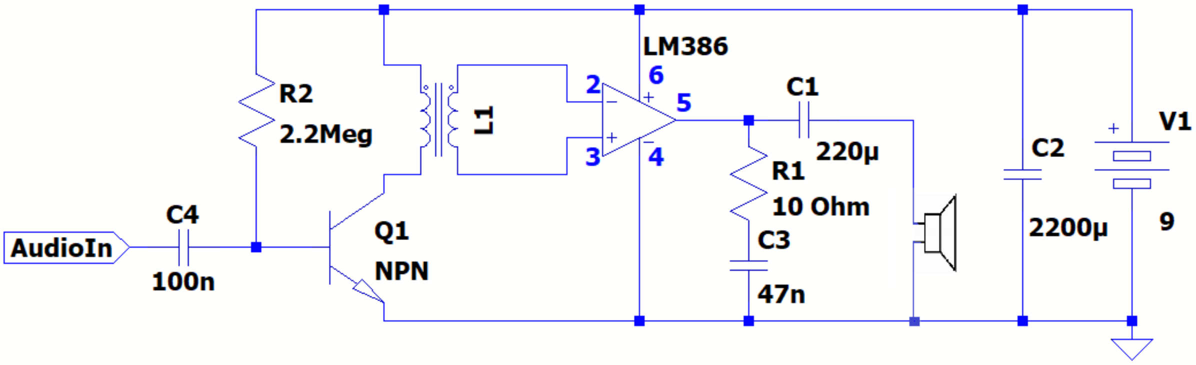

Figure 31. A high gain audio amplifier.

Circuit 22. A folded cascode radio frequency amplifier.

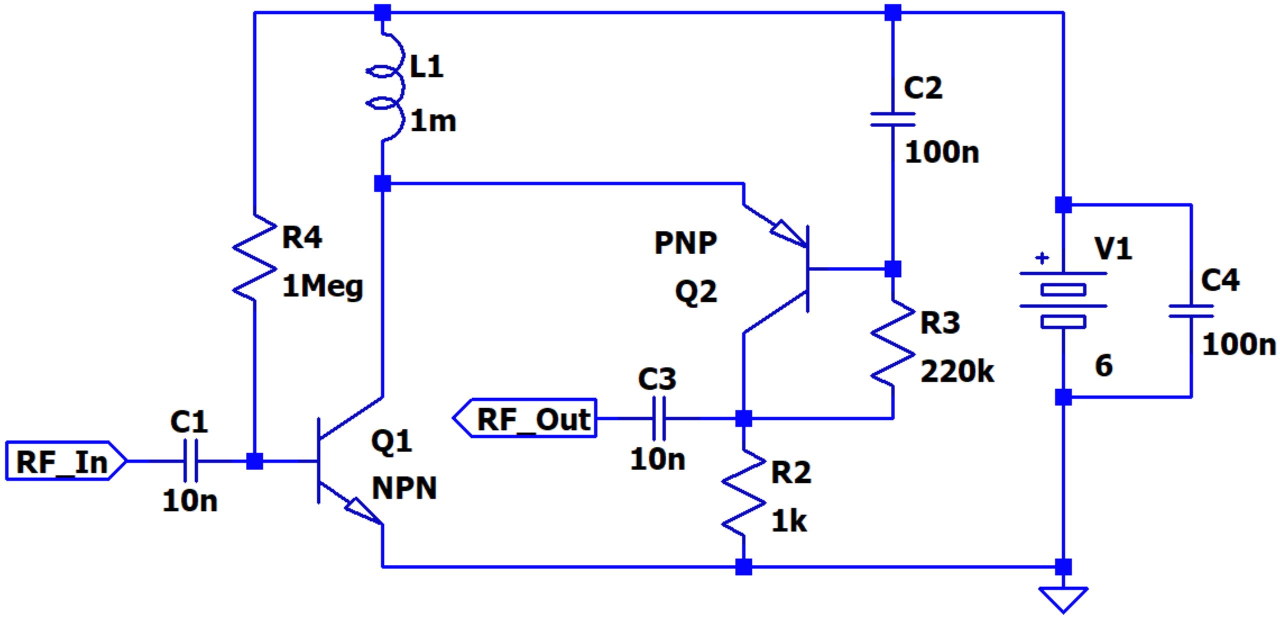

Figure 32. A folded cascode RF amplifier that gives high gain up to 30 Mhz.

Q1 acts as a common emitter amplifier. L1 allows DC current to flow through but has a high impedance at radio frequencies. The low impedance at the emitter of Q2 damps out any resonance effects from L1 and prevents Miller effect feedback from the collector of Q1 to the base of Q1. Allowing good high frequency performance. Q2 then acts as a common base amplifier with the amplified RF signal appearing at its collector. R2 should not be replaced by an undamped inductor of any kind since any leakage capacitance between the collector and emitter of Q2 could then cause unwanted oscillation. Using standard transistors the circuit will work well up to 30 MHz with a 50-ohm RF source, or up to 10 MHz with a higher impedance source.

Circuit 23. A power supply noise floor improver.

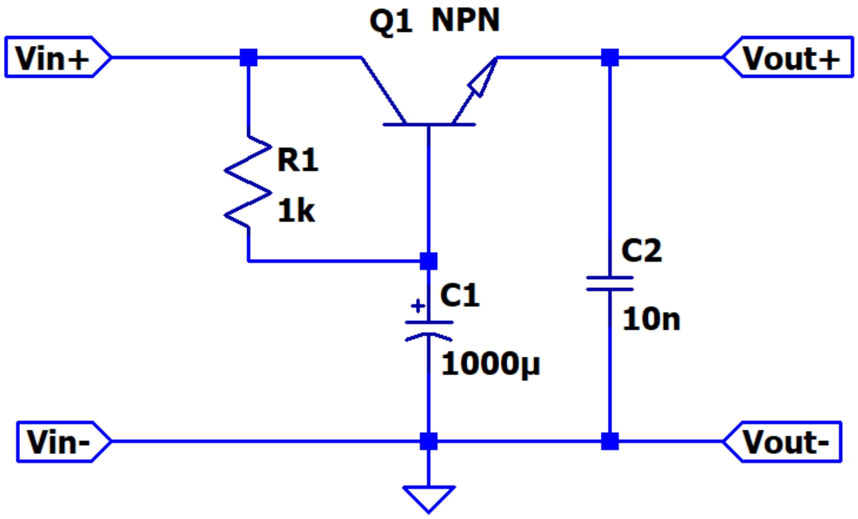

Figure 33. A power supply noise improver.

This circuit will remove the last few 10s of millivolt ripple and noise from a power supply output. You can use it to supply sensitive audio equipment, for example. For high power applications it is possible you may need to protect the base emitter junction of Q1 from over current situations during turn off. You could put a low value resistor between the base of Q1 and the positive connection of C1 to limit the maximum current.

Analog audio power amplifier chips for automotive applications can be very robust, however they often have poor supply line noise rejection, especially when used with a simple bridge rectifier and smoothing capacitor power supply. You can use this circuit to clear up the last traces of loudspeaker hum.

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